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Request for grant of a patent

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1.	Your reference	A10562GB-DJL
2.	Patent application number *(The Patent Office will fill in this part)*	0208036.4 — 08APR02 E709322-1 D02811 P01/7700 0.00-0208036.4
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Honeywell Normalair-Garrett (Holdings) Limited Westland Works Yeovil Somerset BA20 2YD
	Patents ADP number *(if you know it)*	7937917001
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	Air Conditioning System
5.	Name of your agent *(if you have one)*	Forrester Ketley & Co.
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Chamberlain House Paradise Place Birmingham, B3 3HP.
	Patents ADP number *(if you know it)*	133005

		Country	Priority application number *(if you know it)*	Date of filing *(day/month/year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer "Yes" if:* — Yes

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

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Continuation sheets of this form	-
Description	8
Claim(s)	3
Abstract	1
Drawing(s)	1

8

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translation of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	-
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent based on the basis of this application

Signature Forrester Ketley & Co. Date 8 April, 2002

Forrester Ketley & Co.

12. Name and daytime telephone number of person to contact in the United Kingdom — LUCKING, David J. — 0121 236 0484

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PATENTS ACT 1977

A10562GB-DJL

Title: Air Conditioning System

Description of Invention

This invention relates to an air conditioning system and more particularly to such a system for an aircraft.

It is a requirement in an aircraft to supply cool air to a pressurised cabin thereof. Usually the cabin air is recirculated with some of the stale air being refreshed by air obtained from the exterior of the aircraft.

Typically such external air is bled from an engine of the aircraft and is thus pressurised. Such air requires filtering and cooling before being mixed with recirculating air for introduction into the aircraft cabin for breathing and for the maintenance of comfortable conditions.

It is known to cool the air by exchanging heat in the hot pressurised air with cooler ambient air. This may efficiently be achieved by first compressing the bled air to increase its temperature and pressure before cooling the air. Also it is known to cool the air further by expanding the air over an expansion turbine, which also results in some pressure loss in the compressed air.

With conventional systems, hot cabin air is ejected from the air conditioning system and loss of volume is made up by the cooled conditioned bleed air. Thus the heat energy of the hot cabin air which is ejected, is wasted.

Especially where an aircraft is parked on the ground in hot climatic conditions, the cabin air may become very hot and using a conventional air conditioning system, it may take some time after the air conditioning system is started up, e.g. when the aircraft engine or engines are started, or when a ground based support unit is used to provide air to the air conditioning system, for the cabin air to be cooled to a desirable temperature. Thus a considerable amount of heat energy may be wasted.

Avionic systems such as electronic, hydraulic etc. systems produce heat in use, and at least some such systems, particularly electronic systems, require cooling to protect the system components from heat damage. Again heat energy is discarded and thus wasted by conventional avionics cooling systems.

According to one aspect of the invention we provide an air conditioning system for an aircraft in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load from hot cabin air is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

Thus by virtue of an expansion turbine operating more efficiently to cool air whilst minimising air pressure loss, the waste heat in the cabin air is usefully employed to provide energy to improve the cooling efficiency of the expansion turbine.

According to a second aspect of the invention we provide an air conditioning system for an aircraft in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load from a hot avionics system is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

Thus the waste heat produced by the avionics system is usefully employed to provide energy to improve the cooling efficiency of the expansion turbine.

Preferably in an air conditioning system of the invention, in a first mode of operation a heat load from hot cabin air is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine, and in a second mode of operation a heat load from a hot avionics

system is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

It will be appreciated that upon aircraft engine start up, when the cabin air may be much hotter than desired, the air conditioning system may be operated in the first operational mode, whilst when the cabin air is cooled towards a desired temperature, the air conditioning system may be operated in the second operation mode.

Thus the invention provides an air conditioning system in which the control of cabin air flow and avionics system heat loads are integrated.

The invention will now be described with reference to the accompanying drawing which is an illustrative diagram of an air conditioning system in accordance with the invention.

Referring to the drawing an air conditioning system 10 for an aircraft includes a ram air inlet 11 through which ambient air is introduced to the system. On the ground, such air may be driven into the system 10 by a ground based unit, but when the aircraft is in flight the ram air generally is driven into the system 10 due to the movement of the aircraft through the air.

The system further includes another air inlet 12 for air bled from the engine. Such bleed air is hotter than the ram air, and is pressurised.

The hotter bleed air from inlet 12 is fed to a primary heat exchanger 16 where heat is exchanged with the cooler ram air from ram air inlet 11. The cooler ram air from ram air inlet 12 is also used to cool hot air in a secondary heat exchanger 18 as hereinafter described. The thus warmed ram air then returns to ambient, with the assistance of fans 19, 20 as hereinafter described.

The fans 19, 20 will assist in drawing in ram air through ram air inlet 12, particularly when the aircraft is on the ground, and no ground based unit is available, e.g. as the aircraft taxiing.

The air conditioning system 10 includes a two stage compressor/turbine arrangement In a compressing section of the system 10, the cooled bleed air is

first fed from the primary heat exchanger 16 via a duct 22 to a low pressure compressor 23 which thus pressurises and causes heating of the bleed air. From the low pressure compressor 23 the pressurised and heated air is fed along a duct 24 to a high pressure compressor 25 where the air is further pressurised and heated.

The resulting high pressure and hot air is passed to the secondary heat exchanger 18 along a duct 27, and from the secondary heat exchanger 18 the cooled, now warm high pressure air passes along a duct 29 to a cooling section of the system 10. The warm pressurised air is fed from duct 29 to a high pressure water separator 31 via a heat exchanger indicated at 30, where the warm pressurised air is slightly cooled for a purpose hereinafter explained.

The warm pressurised air is then fed via a duct 32 to a first, high pressure, expansion turbine 34 where the warm pressurised air expands and is cooled. From the high pressure turbine 34, the cooled lower pressure air is passed along a duct 35 to a medium pressure water separator 36 further to dry the air, and the medium pressure dried air then passes via a load heat exchanger 38 where the air is warmed, and via the re-heater heat exchanger 30 where it is further warmed, via a duct 40 to a second low pressure expansion turbine, where the air is further and substantially cooled and its pressure reduced. The cold air passes from the second expansion turbine 41 via a duct 42 to a mixing box 43 from which air is supplied to an aircraft cabin 44, 45. Two ducts are shown leading from the mixing box to respective parts of the cabin 44, 45, e.g. a main cabin part and the aircraft's flight deck. Air recirculated from the aircraft cabin 44, 45 via a recirculating loop 46 with fan 60 is mixed with the cold air from the duct 42 in the mixing box 43. An outlet for stale air from the cabin 44, 45 to ambient atmosphere is indicated at 47, including a valve for controlling such outlet.

In this example, the low pressure compressor 23 and the second low pressure turbine 41 are carried on a common shaft 51 such that the compressed

air expanding across the turbine 41 drives the low pressure compressor 23. Furthermore one (20) of the fans 19, 20 which is effective to eject warmed ram air from the system 10 is also provided on the shaft 51 and is thus driven by the expanding compressed air.

The first high pressure expansion turbine 34 is carried on a shaft 50 on which the high pressure compressor 25 and other fan 19 are carried so that the high pressure compressor 25 and fan 19 are driven by the pressurised air expanding across the first turbine 34.

It can be seen from the drawing that in the compressor section of the system 10 there is a valve controlled by-pass 53 from the duct 22 to the first compressor 23, to the duct 24 between the low pressure compressor 23 and the high pressure compressor 25, and a further valve controlled by-pass 54 from the duct 24 to duct 27 from the high pressure compressor 25, so that the high pressure compressor 25 can be by-passed as permitted by the valve. Also, there is a valve controlled by-pass 55 from the duct 27 to the duct 29 from the secondary heat exchanger 18.

In the cooling section of the system 10 there is a valve controlled by-pass 56 from the duct 32 to the first turbine 34 to the outlet of the turbine 34, a valve controlled by-pass 57 from the duct 29 from the secondary heat exchanger 18 to the outlet duct 35 from the first turbine 34, and a valve controlled by-pass 58 from the duct 40 to the second expansion turbine 41, to the cold air duct 42 from the second expansion turbine 41.

The valves of the by-passes 53, 54, 55, 56, 57, 58 may be operated by a system controller (not shown) to balance the system 10 in various operating conditions, and to ensure that the cold air entering the mixing box 43 is of a desired temperature and pressure.

It will be appreciated that when the aircraft is on the ground particularly in hot climates, the cabin temperature can rise significantly, for example to 55°C. Conventionally upon system start-up such hot cabin air has simply been

recirculated until the air is cooled by mixing with cold air in the mixing box 43, to a desired cabin temperature. Thus the heat of the cabin air is lost from the system 10. A proportion of the air in the cabin 44, 45 may be ejected to ambient as indicated through the outlet 47, so that a proportion of the cabin air 44 is refreshed by the air from the air conditioning system 10.

In accordance with the present invention, the system 10 provides a means for recovery of heat energy from hot cabin air.

Cabin air is recirculated from the cabin 44 with fan 60 assistance, and a proportion of the hot cabin air may thus be diverted by a valve 64 via a duct 62 to the load heat exchanger 38 through which the medium pressure air from the first expansion turbine 34 passes. Thus heat from the hot cabin air is used to warm the cooled medium pressure air prior to passing to the second expansion turbine 41.

This is useful because an expansion turbine operates most efficiently at cooling hotter air without losing pressure. Thus the medium pressure cooled air from the first expansion turbine 34 is heated by the hot cabin air in the load heat exchanger 38 so that the second expansion turbine 41 can operate most efficiently at producing cold air for mixing with recirculated cabin air in the mixing box 43. Heat recovered from the load heat exchanger 38 and/or the reheater 30 can be used by the first turbine 34 to increase its rotating speed, boost its pressure ratio, and increase the expansion of air across the turbine. This provides more cooling for a given mass flow.

It is for the same reason that the re-heater heat exchanger 30 is provided to warm the warm air from the secondary heat exchanger 18, before that air is fed to the first expansion turbine 34.

When the aircraft cabin 44 air has cooled towards a desired temperature, the cabin air may no longer be diverted into duct 62. The amount of cabin air, if any, diverted to duct 62 may be controlled by the valve 64 under the control of the system controller.

However as the aircraft is used, other avionic systems 68 of the aircraft may produce heat. Such systems 68 may be for example navigational or other instrumental systems, hydraulic, electronic or any other system which produces heat. At least some of these systems, especially electronic systems, require cooling.

Whereas conventionally, such heat produced by the avionics system 68 would be lost after cooling, in the present invention, such heat energy may usefully be used, by feeding a coolant such as air in heat exchange relationship with the avionics system 68 to be cooled, along a duct 70 (including a non-return valve 71) to the load heat exchanger 38. A fan 72 in the duct 70 is operated to regulate the amount of cooling of the avionics system 68, depending upon the system 68's temperature and whether cabin air is also being fed to the load heat exchanger 38. The return duct from the load heat exchanger 38 has a duct 66 branching off it, to lead to a valve 65 where it joins the recirculating loop 46.

In normal flight when the cabin 44 has been cooled to a desired temperature, this temperature may readily be maintained without diverting cabin air to the load heat exchanger 38 and thus in flight, when the avionics systems 68 are creating the most heat, the load heat exchanger 38 may recover that heat energy as described.

Various modifications may be made without departing from the scope of the invention. Particularly the system 10 described and shown in the drawings includes a low pressure air conditioning machine provided by the shaft 51 and the first compressor 23 and second expansion turbine 41 and a high pressure air conditioning machine provided by the shaft 50, the second compressor 25 and the first expansion turbine 34, each machine including on a common shaft 51, 51 a respective fan 20, 19. In another arrangement, only one fan 19, 20 may be provided, and the compressors 23, 25 and expansion turbines 34, 41 may be provided otherwise than on respective common shafts 50, 51.

Although the re-heater heat exchanger 30 is preferably provided, this is not essential.

A proportion of the cabin 44 air may be disposed of to allow for air refreshment otherwise than as described through outlet 45.

As described above, either the hot cabin air is diverted to the load heat exchanger 38 when the cabin air is above a desired or predetermined temperature range, in a first operating mode, or the heat load from the hot avionics system 68 is provided to the load heat exchanger 38 in a second operating mode. If desired, heat load from the cabin air and avionics system 68 may be provided to the load heat exchanger 38 during a transition phase before the cabin air has been cooled to below the predetermined temperature range and whilst the avionics system 68 is hotter than another predetermined temperature.

The valves 64, 65 shown in the system above may be modulating valves of suitable type, and may be controlled in respect of their operation to operate in a predetermined relationship to one another.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS

1. An air conditioning system for an aircraft in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load from hot cabin air is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

2. An air conditioning system for an aircraft in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load from a hot avionics system is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

3. An air conditioning system for an aircraft in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which in a first mode of operation a heat load from hot cabin air is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine, and in a second mode of operation a heat load from a hot avionics system is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

4. A method of operating an air conditioning system in an aircraft of the kind in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine, the method including diverting a heat load being hot cabin air to the heat exchanger.

5. A method of operating an air conditioning system in an aircraft of the kind in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine, the method including providing the heat load from a hot avionics system to the heat exchanger.

6. A method of operating an air conditioning system in an aircraft of the kind in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine, the method including in a first mode of operation, diverting a heat load being hot cabin air to the heat exchanger, and in a second mode of operation providing the heat load from a hot avionics system to the heat exchanger.

7. A method according to claim 6 wherein the first mode of operation of the method is performed when the cabin air is hotter than a predetermined temperature range, and the second mode of operation of the method is performed when the cabin air is at or below the predetermined temperature range.

8. A method according to claim 6 or claim 7 wherein the first and second modes of operation of the method are performed concurrently during a transition phase as the cabin air temperature is above the predetermined temperature range and the avionics system is hotter than another predetermined temperature range.

9. An air conditioning system for an aircraft, or a method of operating same, substantially as hereinbefore described with reference to the accompanying drawing.

10. Any novel feature or novel combination of features described herein and/or in the accompanying drawings.

ABSTRACT

Title: Air Conditioning System

An air conditioning system for an aircraft in which cabin air is recirculated and mixed with cold air from an air conditioning machine which includes at least an expansion turbine over which warm pressurised air is expanded and cooled, and wherein the system includes a heat exchanger in which a heat load from hot cabin air and/or a hot avionics system is exchanged with the warm pressurised air prior to the pressurised air being expanded by the expansion turbine.

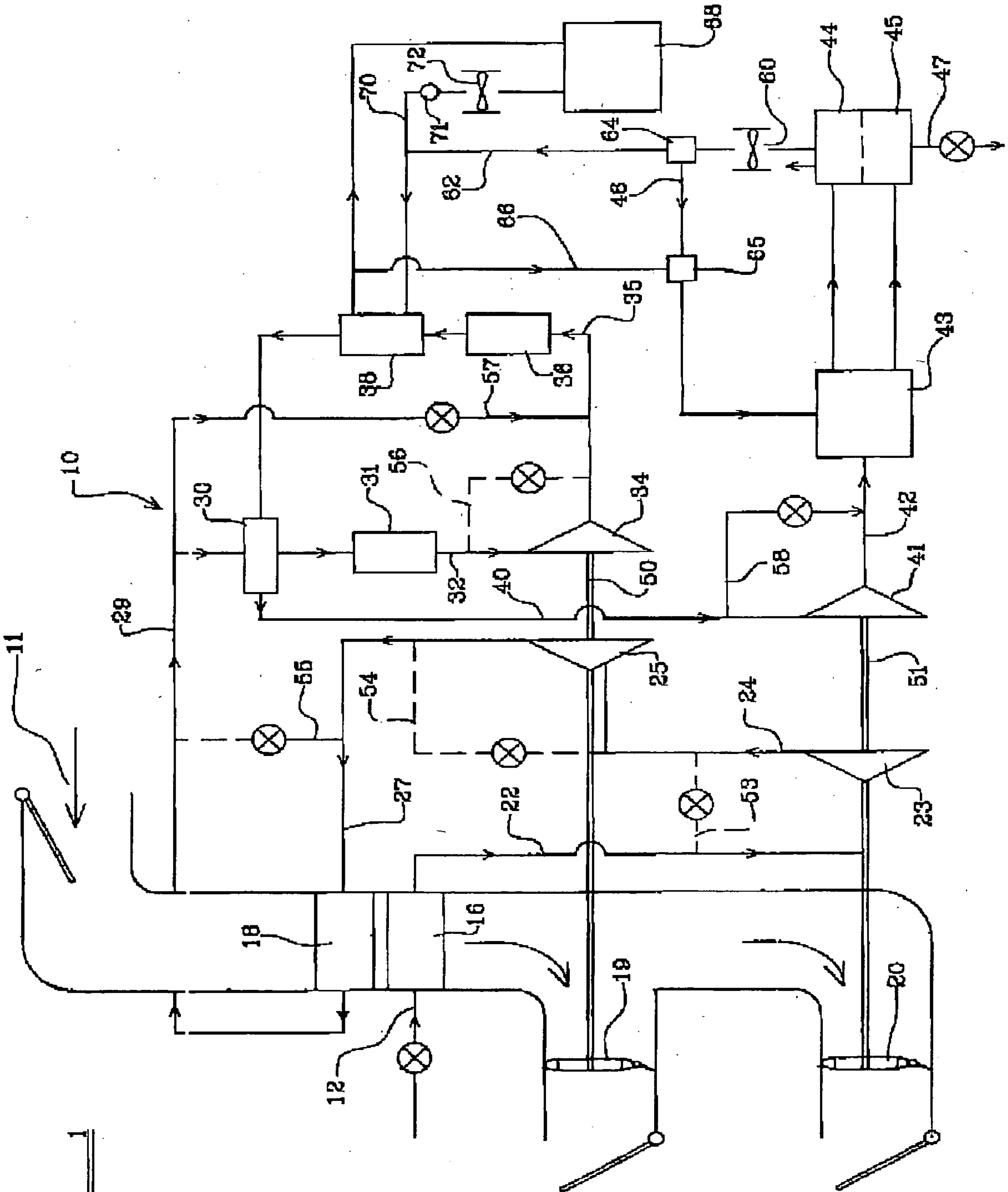

FIG 1